

Do magnetic fields contribute to the dynamical stability of the secondaries of CVs against mass transfer?

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ABSTRACT

We show the presence of CVs with orbital periods in the range 3.5-7 h and mass ratios $q = M_2/M_1$ above the critical values for dynamically stable mass transfer. We explore whether the magnetic fields produced in the secondaries alter the theoretical mass ratio limits allowing dynamical stability. Since magnetic fields change the specific heats and the polytropic exponent γ of the gas in the convective envelope, the mass-radius adiabatic exponent ξ_{ad} also changes. We find that turbulent magnetic fields can produce 10% less restrictive critical q -profiles while large-scale toroidal and poloidal fields have smaller effects. Thus, magnetic fields alone do not account for the stability of all the anomalous CVs. However, we found that the small variations of ξ_{ad} induced by solar-type magnetic cycles explain the amplitudes of the cyclic accretion luminosity variations shown by several CVs.

Subject headings: stars: cataclysmic variables, mass transfer, magnetic fields

1. Introduction

Cataclysmic Variables (CVs) are semidetached binary systems formed by a white dwarf (WD) primary accreting matter from a Roche lobe-filling secondary, usually a low mass main sequence star. The WD is surrounded by an accretion disk, unless its magnetic field is strong enough to partially or totally control the accretion geometry; these two cases correspond to the *Intermediate Polar* systems and the *Polar* systems, respectively.

CVs are thought to lose angular momentum through magnetic braking and gravitational radiation. The shrinking of the Roche lobe of the secondary produces the mass overflow

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through the inner Lagrangian point and accretion onto the WD. Thus, CVs are generally evolving towards shorter orbital periods and less massive secondaries. The luminosity of a CV is mainly produced by the thermalization of the potential energy released by the accretion stream.

Very few objects have been observed at orbital periods in the range 2-3 h, called the period gap (PG). This is generally explained by the disrupted magnetic braking model (Rappaport, Verbunt & Joss 1983; Spruit & Ritter 1983). When the orbital period gets close to 3 h, the mass losing secondary becomes fully convective and the efficiency of the magnetic braking suddenly decreases. As the mass transfer rate drops, the secondary tends to recover its thermal equilibrium shrinking inside its Roche lobe and the CV is *switched off*. Mass transfer would then start again only when angular momentum losses due to gravitational radiation have brought the secondary back in contact with its Roche lobe, which typically occurs at approximately 2 h of orbital period.

Not only does the history of the mass transfer rate of a CV characterize its secular evolution, but it also characterizes the behavior of some subclasses of CVs. For example, dwarf novae (DN) have relatively low accretion rates so their disks can be thermally unstable and produce cyclic instability phenomena. Old novae and nova-like systems, instead, are systematically brighter than DN suggesting that their accretion disks are powered by larger mass transfer rates. In this case, the higher temperatures of the accretion disks would in most cases prevent the onset of the instability phenomenon. However, the most important difference between novae and dwarf novae is represented by the requirement that the primaries of nova systems must have masses larger than $\sim 0.5M_{\odot}$ in order to produce ejecta (Livio 1992). The spread of the observed mass transfer rates in CVs and, perhaps, also the existence of various subclasses at any given orbital period, might have several causes. The presence of magnetic cycles of activity in the secondaries (Bianchini 1987, 1990; Warner 1988; Richman, Applegate & Patterson 1994) account only for luminosity changes of a few tenths of a magnitude. More important mechanisms could be a variable efficiency of the envelope chaotic dynamo combined with that of the boundary layer dynamo (Zangrilli, Tout & Bianchini 1997), secular mass transfer cycles excited by the irradiation of the secondary by the primary (King et al. 1996), and/or the hibernation scenario for classical novae proposed by Shara et al. (1986).

A CV emerging from common envelope (CE) evolution (Paczynski 1976) must experience stable mass transfer from the Roche lobe filling secondary on to the WD primary. As continuous mass loss perturbs the thermal equilibrium of the secondaries, they are slightly smaller or larger than MS stars when they are predominantly radiative or convective, respectively (e.g. Whyte & Eggleton 1980, Stehle, Ritter & Kolbe 1996, Baraffe & Kolbe 2000).

Generally speaking, the stability of mass transfer is determined by the change in radius of the secondary due to adjustment of its convective outer layers (dynamical stability) and internal structure (thermal stability) in response to mass loss, compared with the changes of the Roche lobe radius induced by both the mass exchange and the angular momentum losses by the system. We define three exponents, ξ_{ad} , ξ_{the} and ξ_{RL2} , for the adiabatic, thermal equilibrium and Roche-lobe mass-radius relations of low-mass MS stars, respectively. Since the time derivative of the radius can be written in the form

$$\frac{\dot{R}}{R} = \xi \frac{\dot{M}_2}{M_2} \quad (1)$$

the binary will be adiabatically and thermally stable against mass transfer only if we have

$$\xi_{ad} - \xi_{RL2} > 0 \quad (2)$$

and

$$\xi_{the} - \xi_{RL2} > 0 \quad (3)$$

respectively. Alternatively, a second CE episode would quickly drive the two components of the newborn CV to coalescence. The $M_2 - \xi_{ad}$ and $M_2 - \xi_{the}$ profiles for stable mass transfer were discussed by Schenker, Kolb & Ritter (1998). They can be easily transformed into two relations between M_2 and the critical mass ratio $q_{critic} = (M_2/M_1)_{critic}$ as described by de Kool (1992) and King et al. (1994). The critical q -profiles for adiabatic and thermal equilibrium stable mass transfer can be described as follows. For secondaries below $\sim 0.45 M_\odot$, the deep convective envelope tends to expand adiabatically in response to mass loss on a dynamical time scale. In this case, the dynamical stability criterion is the most restrictive one and the mass ratios should satisfy the condition $q < q_{dyn} = 0.63$. For masses above $\sim 0.75 M_\odot$, the mass in the convective envelope is too small to produce adiabatic expansion, and the secondary even tends to shrink. As a consequence, dynamical stability is guaranteed even for larger mass ratios while the thermal stability criterion $q < q_{therm} = 1.25$ suddenly becomes the more restrictive one. All CVs are then expected to have mass ratios that are roughly consistent with these stability criteria although exceptions are possible (see next section 2).

In this paper we explore the effects of magnetic fields on the critical q_{dyn} profile of lower mass secondaries. In section 2 we present systems that apparently deviate from the theoretical stability criteria. In section 3 we try to evaluate how magnetic fields modify the critical q_{dyn} profile. The effects of the presence of solar-type magnetic cycles on the mass transfer rate is discussed in section 4. Conclusions are given in section 5.

2. The q -profile of the observed CVs

The Ritter & Kolb (2005) on-line catalogue (hereafter RK2005) reports the masses and the mass ratios for about 102 CVs. The mass transfer stability criteria described by de Kool (1992), King et al. (1994) and Shenker, Kolb & Ritter (1998) roughly state that, for mass companions below $0.45M_{\odot}$, the dynamical stability criterion is the most restrictive one and it must be $q < 0.63$, while, for masses above $0.75M_{\odot}$, as the dynamical stability is achieved even for very large mass ratios, the prescription for thermal stability $q < 1.25$ dominates. The critical $q(M_2)$ values for the dynamically and thermally unstable mass transfer are sketched in the $q - M_2$ plane of Fig. 1 by the solid line (q_{dyn}) and the dashed line (q_{therm}), respectively. The M_2 and q values of the selected sample of CVs are plotted in Fig. 1 using different symbols for different subclasses. Polar and Intermediate Polar systems are circled by open circles and open squares, respectively. Looking at Fig. 1, we first notice that M_2 and q are linearly correlated, as predicted by standard CV models. We also observe that some of the data points are not below the critical q_{dyn} line as requested by the stability criterion. In fact, six CVs fall inside the thermally stable but dynamically unstable region; they are V1043 Cen, LX Ser, HY Eri, AT Ara, CM Del and V347 Pup. We should have also included UX UMa for which RK2005 report $M_1 = M_2 = 0.47M_{\odot}$ (Baptista et al. 1995). However, from new radial velocity curves Putte et al. (2003) derived $M_1 = 0.78 \pm 0.13M_{\odot}$ and $q = 0.60 \pm 0.09$ that places UX UMa just below the limit for mass transfer stability. Five objects almost coincide with the q_{dyn} line; they are the old novae T Aur, HR Del, and DQ Her, the magnetic system V1309 Ori and the nova-like RW Tri. Finally, the recurrent nova CI Aql (Lederle & Kimeswenger 2003) and the dwarf nova EY Cyg (Tovmassian et al. 2002) even appear both thermally and dynamically unstable, but having rather long orbital periods they probably host evolved secondaries. In particular, Gänsicke et al. (2003) suggested that EY Cyg might have passed through a phase of (unstable) thermal timescale mass transfer that produced a CNO-enriched secondary stripped of its outer layers. Pollution of the secondary of CY Cyg caused by an unrecorded nova explosion was also suggested by Sion et al. (2004). Somewhat evolved secondaries might also exist in short orbital period systems and, in any case, secondaries are mass losing stars out of thermal equilibrium. Thus, the theoretical prescriptions for the dynamical stability of actual CVs are probably different from those predicted for MS secondaries. In this paper we suggest that the critical q -profile could be also modified by the magnetic fields produced in the convective envelopes of the secondaries.

Fig. 2 plots M_2 versus M_1 . Filled circles represent masses that have been determined spectroscopically; open circles, instead, refer to mass estimates obtained from empirical correlations. These two classes of data points are indistinguishable in the diagram. The

errorbars of the suspected unstable objects are shown. Only V1043 Cen and LX Ser can be considered unstable at a 95% confidence level. The six systems that fall inside the dynamically unstable region are characterized by $M_{2(mean)} = 0.38 \pm 0.1 M_{\odot}$ and $M_{1(mean)} = 0.55 \pm 0.1 M_{\odot}$. We notice that these ‘unstable objects’ are dynamically but not thermally unstable (see Fig. 2). The only exception is the peculiar dwarf nova EY Cyg discussed above. The weak correlation between the masses of the two components observed in Fig 2 is probably only due to the selection effects introduced by the thermal stability criterion. Fig 2 suggests that apparently unstable CVs tend to cluster around masses of the secondaries that correspond to orbital periods above the period gap. Since the masses of the primaries are very weakly correlated with the orbital period because they have only to obey to the mass ratio limits for stability, unstable systems must also select the less massive primaries.

In order to investigate the nature of these apparently dynamically unstable CVs, we plot in Fig. 3 the mass-period diagram. Different symbols are like in Fig. 2 and basically show the same statistics. Empirical mass-period relationships were given, amongst others, by Warner (1995a,b), Smith & Dhillon (1998), Howell & Skidmore (2000), and Patterson et al. (2003). Smith & Dhillon (1998) found that the secondary stars in CVs with periods below 7-8 h are indistinguishable from main-sequence stars. As an example, we show in Fig. 3 how data points are fitted by the Patterson et al.’s correlation (dashed line). The solid line represents the evolutionary track of a $1.0 M_{\odot}$ secondary obtained using the two-dynamos evolutionary code developed by Zangrilli, Tout & Bianchini (1997). The fit is particularly significant around and through the period gap, especially for filled circles. With the exception of V1309 Ori and AT Ara, the unstable systems candidates (labelled by crosses) that apparently possess unevolved secondaries do not follow any distinctive pattern and fall in the range $3 < P_{orb} < 6$ h, corresponding to masses of the secondaries in the range $0.3 - 0.7 M_{\odot}$.

It is however possible that mass transfer stability condition (2), also sketched in Fig. 1, is not applicable to the secondaries of some CVs because their convective shells follow a mass-radius relation that implies larger ξ_{ad} exponents. Actually, the adopted stability criteria might be uncertain, the masses of the two components could be poorly determined, and a significant fraction of short-period, angular momentum-driven CVs seem to have a somewhat evolved donor star (e.g. Kolb & Baraffe 2000, Kolb & Williams 2005).

In all cases, in the next paragraph we will focus our attention on the role played by the magnetic fields produced in the convective envelopes of the secondaries in changing the ξ_{ad} exponent and the critical q_{dyn} -profile.

3. How magnetic fields in the secondaries modify the critical q -profile of CVs

It is widely recognized that magnetic fields, increasing the critical Rayleigh number, inhibit convection (see, for example, van den Borgh 1969). The possibility that convection inside stars might be suppressed by strong magnetic fields of simple geometry, namely, poloidal and/or toroidal, was discussed by Gough & Tayler (1966) and Moss & Tayler (1969, 1970). A detailed solar model containing a large-scale "magnetic perturbation" to mimic the strong fields associated with an $\alpha - \Omega$ -type solar dynamo was constructed by Lyndon & Sofia (1995). They found that the changes in the temperatures and the adiabatic gradient produced by the magnetic perturbation lead to quite large decreases in the convective velocities above the perturbed region and to considerable increases of the convective turnover time.

Even neglecting boundary-layer dynamos, which are responsible for the large scale structure of the stellar poloidal field, chaotic envelope-dynamos driven by convective turbulence are sufficient to produce magnetic energy densities comparable to the kinetic energy, that is at a level close to global equipartition (Thelen & Cattaneo 2000). Liao & Bi (2004) found that turbulent magnetic fields can also inhibit the generation of convection. We might then think that if magnetic fields can reduce the efficiency of convection, they should also reduce their adiabatic response to mass loss. However, since the prescription for dynamical stability is $\xi_{ad} - \xi_{RL2} > 0$, we should mainly investigate whether magnetic fields can modify the adiabatic mass-radius exponent ξ_{ad} .

For stars with extended convective layers, that means for masses $\leq 0.5M_{\odot}$, an approximated expression of the mass-radius adiabatic exponent given by Paczyński (1965) is

$$\xi_{ad} = \frac{\gamma - 2}{3\gamma - 4} \quad (4)$$

where $\gamma = c_p/c_v$ is the polytropic exponent for an adiabatic transformation and c_p and c_v are the specific heats. The ξ_{ad} -vs- γ diagram is shown in Fig. 4. For an ideal gas and isotropic turbulence we have $\gamma = 5/3$ and $\xi_{ad} = -1/3$, which, in Fig. 1, corresponds to the $q = 0.63$ critical mass ratio for the dynamical stability of secondaries below $0.5M_{\odot}$. From Fig. 4 we may see that, if we chose γ values below $4/3$ or above $5/3$, we obtain $\xi_{ad} > -1/3$ and thus steeper mass-radius relations that lead to less restrictive critical q -profiles for low mass secondaries.

The corrections to the thermodynamical variables due to the presence of a turbulent magnetic field derived by Liao & Bi (2004) are

$$\Delta c_v = \beta_m \frac{k}{\mu m_u} \quad (5)$$

$$\Delta c_p = 2\beta_m \frac{k}{\mu m_u} \quad (6)$$

$$\Delta\gamma = \frac{1}{c_v} \Delta c_p - \frac{c_p}{c_v^2} \Delta c_v (2 - \gamma) \frac{\Delta c_v}{c_v} \quad (7)$$

where β_m is the ratio of magnetic pressure to gas pressure, while k , μ and m_u have their usual meaning. As we can see, a turbulent magnetic field tends to increase the specific heats and γ . Assuming an initial $\gamma = 5/3$, the increment of the polytropic exponent can be written as $\Delta\gamma \sim (0.33/c_v)\beta_m k/(\mu m_u)$. Fig. 5 plots the mass-radius exponent ξ_{ad} derived from eq. (4) as a function of β_m , for complete and partial hydrogen ionization, assuming unperturbed specific heats $c_v/(\frac{3}{2}N_0k) = 2$ and $c_v/(\frac{3}{2}N_0k) = 35$, respectively (Clayton 1983, table 2-4), N_0 being the Avogadro number. If we focus on the full ionization line in Fig. 5 we find for $\beta_m = 0.01$ an increase $\Delta\gamma/\gamma = 1.6 \times 10^{-3}$, which is in good agreement with the numerical results obtained by Mollikutty, Das & Tandon (1989) when we use the values of the specific heats listed in their Tables 1 and 2. We conclude that chaotic dynamos can produce critical q-profiles above the minimum standard value $q_{dyn} = 0.63$ for low mass secondaries (see Fig. 1), but probably not much above $q \sim 0.7$ even for large β_m 's. This result shows that the modified critical q-profile accounts for the stability of the border line systems of Fig 1.

If we consider large-scale, geometrically structured magnetic fields, like those generated by $\alpha - \Omega$ -type dynamos, then the magnetic extra pressure is no more a simple scalar and γ will strongly depend on the field geometry. Since the magnetic force component along the magnetic field is zero, in that direction a magnetically controlled gas will show $\gamma = 1$, while, perpendicular to the field, it will be $\gamma = 2$. For fields tangled on distance scales of interest $\gamma = 4/3$, as for a relativistic gas (Endal, Sofia & Twigg 1985). Thus, γ represents the ratio of specific heats for the applied perturbation. In practice, the effective polytropic exponent of a convective envelope should be calculated for any given field geometry, distribution and intensity and averaged over the whole convective shell. In particular, as stellar structures mainly depend on the radial variations of the total pressure, we will only consider the radial dependence of the magnetic pressure and the polytropic exponent. Lyndon & Sofia (1995) studied the effects on the solar structure produced by localized large-scale magnetic fields with no radial component, i.e. a toroidal field with a radial pressure component, and assumed $\gamma = 2$. Similarly, the toroidal fields rising from the overshoot regions of secondaries with masses between 0.3 and 0.5 M_\odot might also produce strong localized magnetic perturbations with $5/3 < \gamma < 2$. Poloidal fields, instead, appear radial only at large latitudes and could, in principle, produce perturbations with $1 < \gamma < 5/3$. We recall that radial fields should much more strongly inhibit convection (Moss & Tayler 1969).

However, since magnetic pressure is, on the average, a small fraction of gas pressure, the effective polytropic exponent of the convective shell should not greatly differ from the

unperturbed value $\gamma = \frac{5}{3}$. Looking at Fig. 4, we see that, for small changes of γ , the initial value of the adiabatic exponent $\xi_{ad} = -\frac{1}{3}$ can increase or decrease whether the geometry of the magnetic perturbation corresponds to $\gamma = 2$ or to $\gamma = 1$, respectively. However, the $\gamma = 2$ geometry very likely dominates most of the stellar envelope because large-scale poloidal fields are weaker than the toroidal ones and because they become radial only near the magnetic poles. Thus, we may roughly describe the effects of large scale fields using the same approach as for turbulent fields, assuming β_m as the ratio of the radial component of the combined toroidal and poloidal magnetic pressure, $B_{tot}^2/8\pi$, to gas pressure. According to Applegate (1992), the magnetic torques which are active in the outer convective regions of the secondaries should be produced by fields of several kilogauss. Toroidal fields of some 10^4 G produced by $\alpha - \omega$ dynamo models were suggested by Zangrilli, Tout & Bianchini (1997) in CVs just above the period gap. Since equipartition, i.e. $\beta_m = 1$, in the envelopes of low mass secondaries typically requires fields of $\sim 10^8$ G, the ratio of magnetic to gas pressure is $\beta_m \sim 10^{-4}$. This small value however becomes ~ 100 times larger at the photosphere (Applegate & Patterson 1987). Assuming $\beta_m \sim 10^{-4}$, equations 5-7 yield $\Delta\gamma \sim 3 \times 10^{-5}$, while from eq. 4 we obtain $\Delta\xi_{ad} \sim 5 \times 10^{-5}$. We conclude that large-scale toroidal and poloidal fields should not significantly contribute to increase the stability of fully, or almost fully convective secondaries, their effects being smaller than those produced by chaotic fields.

Possible effects due to the presence of magnetic torques in the outer convective regions should also be investigated. Applegate (1992) explained that the field lines rising from the magnetic dynamo in the overshoot region produce a negative torque in the outer envelope trying to spin down the tidally locked outer layers of the secondary. In this case, an observer corotating with the binary would see the surface of the star rotate in a retrograde sense. The consequent change in the quadrupole moment of the star would then produce the orbital period modulations observed in some CVs during magnetic cycles. Richman, Applegate & Patterson (1994) have shown that a consequence of the decreased rotation of the outer envelope is the appearance of an inward directed Coriolis acceleration. Following these authors, we find that for orbital periods around 4 h and $\sim 0.45 M_\odot$ secondaries, the mean extra-gravity due to Coriolis forces is $\sim 10^2 \text{ cm s}^{-2}$. Since this is only 10^{-3} times the surface gravity, some effects could be seen only in the photosphere and the thin radiative layer above. Another consequence is that the energy stored and dissipated in the convective zone, where a peak of differential rotation is cyclically set up by magnetic cycles, will produce a modulation of the stellar luminosity of the order of $\Delta L/L \sim 0.1$, corresponding to changes in the effective temperature $\Delta T_{eff}/T_{eff} \sim 0.025$. In Applegate's model, the release of the stored torque energy should heat not only the stellar surface, but most of the convective shell as well. Since in most of the convective region the temperatures are above the HeII ionization

limit, the Rosseland mean is dominated by Kramers’ law. Thus, inside the convective shell, a 3% increment of the temperature should produce a $\sim 10\%$ decrease in the opacity coefficient. The result should be a less developed convection zone and a hotter photosphere, the effect being more pronounced as the mass of the secondary increases (Pizzolato et al. 2001). Instead, in the cool atmospheres, small temperature increments should determine substantial increases of the mean opacity and the atmospheric radiative gradient. As a result, the photospheric radius should increase. However, whether the combined effects of all these mechanisms will result in a steeper mass-radius relation with a larger ξ_{ad} could be understood only by performing numerical simulations with full stellar models.

4. The effects of magnetic cycles on the mass transfer rate

Since $\alpha - \Omega$ -type dynamos are characterized by periodic solutions (magnetic cycles), we wonder whether the presence of weakly variable γ and ξ_{ad} might represent an additional/alternative mechanism modulating the mass transfer rate within the binary system. Following Osaki (1985), Warner (1988) and Richman, Applegate & Patterson (1994), we may express the fractional change in the accretion rate as

$$\Delta\dot{M}_2/\dot{M}_2 = \Delta R/H \quad (8)$$

where H is the photospheric pressure scale height that, for a lower main sequence star, is ~ 3200 times smaller than the radius R , and ΔR is here assumed as the variation of the stellar radius produced by a change of ξ_{ad} . We may then rewrite expression 8 as

$$\Delta\dot{M}_2/\dot{M}_2 \sim 3200 \times \Delta R/R \quad (9)$$

and, since

$$\Delta R/R \sim \ln M \Delta \xi_{ad} \quad (10)$$

we obtain, for a $0.5 M_\odot$ secondary, $\Delta\dot{M}_2/\dot{M}_2 \sim 0.1$. Actually, this is the order of magnitude of the observed long-term luminosity variations of CVs which are usually ascribed to the presence in the secondaries of solar-type cycles (Bianchini 1987, 1990; Warner 1988; Richman, Applegate & Patterson 1994).

5. Conclusions

A few CVs with orbital periods in the range 3.5-7 h have mass ratios that would define them as thermally stable but dynamically unstable (Fig. 1). Assuming that the masses

of the two companions are fairly well determined and the secondaries are MS stars, the commonly adopted criteria do not explain the stability of these systems against mass transfer. However, we found another effect since chaotic and large-scale magnetic fields produced in the convective shells of the secondaries modify the polytropic γ exponent, the mass-radius adiabatic exponent ξ_{ad} and, consequently, the critical q -profile for stable mass transfer. We demonstrated that large β_m 's turbulent magnetic fields might produce critical q -profiles 10% higher than the usually adopted minimum critical value $q_{dyn} = 0.63$ for low mass secondaries. We found that the contribution by large-scale toroidal and poloidal fields could be smaller. Thus, magnetic fields alone cannot account for the stability of all the anomalous CVs identified in Fig. 1 and other explanations must be investigated.

During this study, we found another important effect due to the magnetic fields of the secondaries. In fact, since toroidal and poloidal fields are produced by $\alpha - \Omega$ -type dynamos, their intensities should vary throughout magnetic cycles, inducing periodic changes in the mass-radius adiabatic exponent ξ_{ad} . We have demonstrated that these variations, though small, are sufficient to explain the cyclic mass transfer rate variations observed in a number of CVs.

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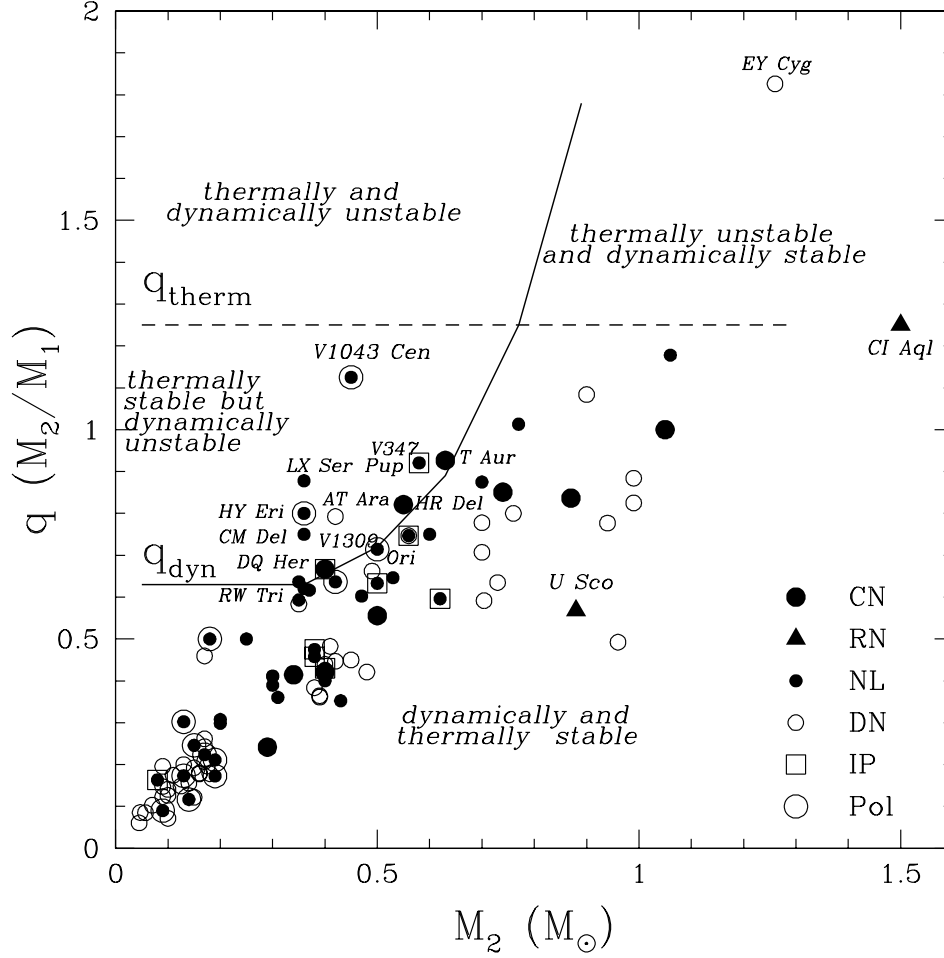


Fig. 1.— Plot of mass ratios versus the masses of the secondaries (from RK2005). *Open circles* represent dwarf novae; *small solid circles* represent nova-like systems; *large solid circles* are classical novae; the *solid triangles* are recurrent novae. Symbols surrounded by *open squares* are intermediate polars while those surrounded by *open circles* are polars. The critical line for dynamical stability q_{dyn} (solid line), and that for thermal stability q_{therm} (dashed line), are shown. Six objects fall inside the thermally stable but dynamically unstable region (see text). Their error bars are shown in Fig. 2.

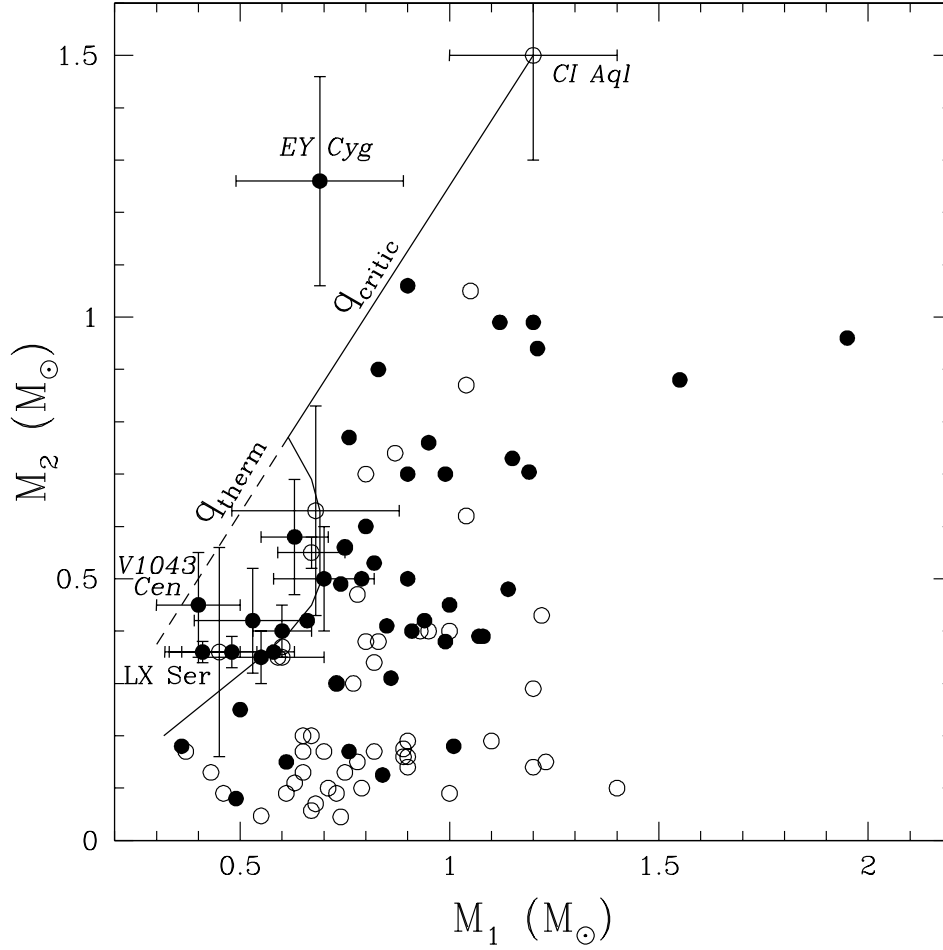


Fig. 2.— Plot of the masses of the components. Here, *filled circles* refer to spectroscopic determinations, while *open circles* mean that the mass of the secondary was derived from empirical correlations (namely, the orbital period). The q_{critic} line is shown by a solid line; the dashed line shows the upper limit for thermal stability. The unstable systems are plotted with their error bars. Most of them tend to cluster around $M_1 \sim 0.55 M_\odot$ and $M_2 \sim 0.38 M_\odot$ (see text). V1043 Cen and LX Ser are unstable at a 95% confidence level.

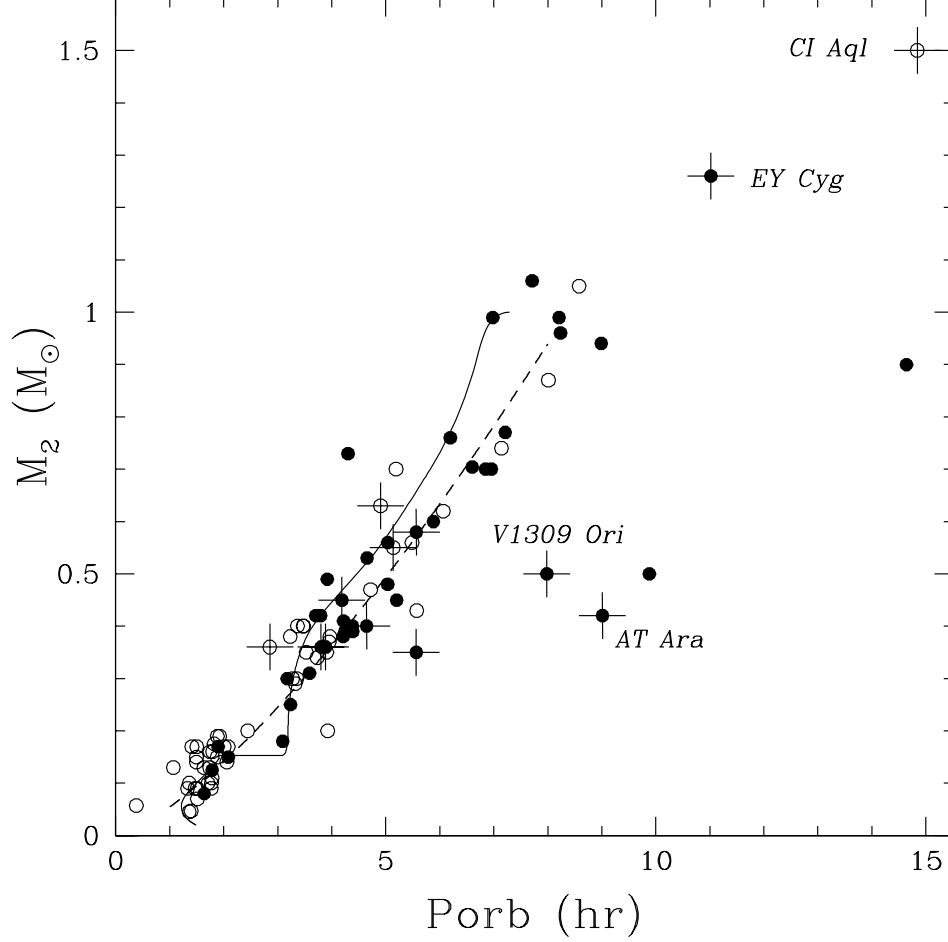


Fig. 3.— The $M_2 - P_{orb}$ correlation. The dashed line represents the empirical law by Patterson et al. (2003). The solid line is the evolutionary track of a $1.0 M_\odot$ secondary. Symbols are like in Fig. 3. In this diagram, with the exception of V1309 Ori, AT Ara and the long-period recurrent nova CI Aql, unstable objects, marked by crosses, do not show any distinctive pattern.

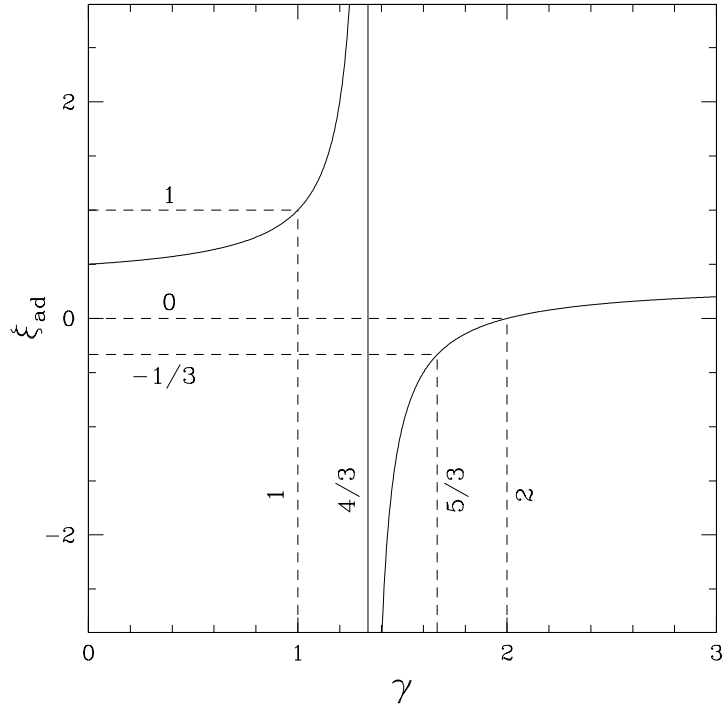


Fig. 4.— The $\xi_{ad} - \gamma$ diagram for secondaries with extended convective envelopes, namely, with masses $\leq 0.5M_{\odot}$.

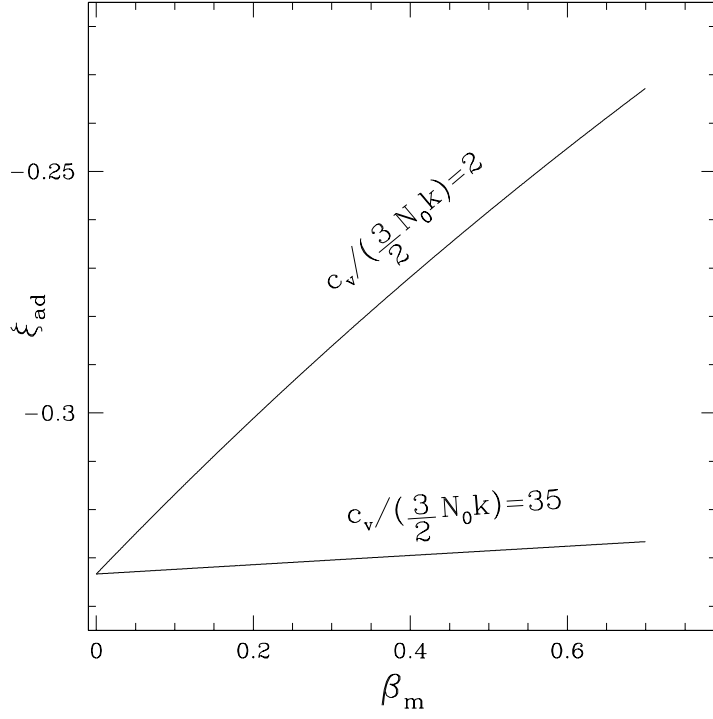


Fig. 5.— The mass-radius adiabatic exponent ξ_{ad} as a function of β_m for turbulent magnetic fields. The cases of complete and partial (50%) hydrogen ionization are labelled by the values $c_v/(\frac{3}{2} N_0 k) = 2$ and $c_v/(\frac{3}{2} N_0 k) = 35$, respectively.